CHAPTER 3 CRACK SEALING, CRACK FILLING & JOINT SEALING OF FLEXIBLE & RIGID PAVEMENTS

1.0 INTRODUCTION

Cracking in pavements occurs when a stress is built up in a surface layer that exceeds the tensile or shear strength of the pavement causing a fissure or crack to open. Crack sealing and crack filling are methods which can be used to repair these cracks in pavement surfaces. The cause of the crack and its activity play a dominant role in determining the success of crack sealing or filling operations.

This chapter addresses crack sealing and filling techniques associated with flexible hot mix asphalt (HMA) pavements and joint and crack sealing of rigid portland cement concrete (PCC) pavement systems. The reader is advised to pay close attention to the type of pavement system being addressed, as treatment techniques can vary.

1.1 TYPES OF CRACKS

Cracking may be associated with various distress mechanisms. Crack types include: fatigue cracks, longitudinal cracks, transverse cracks, block cracks, reflective cracks, edge cracks, slippage cracks, and joints in PCC pavements (1). Each crack type is discussed below:

1.1.1 Flexible (AC) Pavements

Fatigue Cracking: These cracks form a pattern similar to an alligator's skin as illustrated in Figure 1. They are the result of repetitive traffic loads or high deflections often due to wet bases or sub grades. This type of cracking can also lead to potholes and pavement disintegration. Neither crack sealing or filling can treat this type of failure. Alligator cracking can be preceded by longitudinal cracking in the wheel paths. Caltrans refers to longitudinal cracking in the wheel path as Alligator A and multiple interconnected cracks in the wheel path as Alligator B cracking. Alligator C cracking is multiple interconnected cracking across the entire roadway.

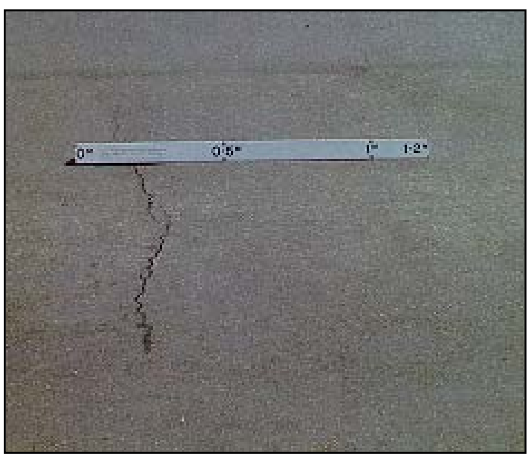
Longitudinal Cracks: These cracks run longitudinally along the pavement, as shown in Figure 2, and are caused by thermal stress and/or traffic loadings. They occur frequently at joints between adjacent travel lanes or between a travel lane and the shoulder, where hot mix density is lower and voids are higher. Longitudinal cracking may be associated with raveling and poor adhesion or stripping. These cracks can be effectively treated with crack sealants.

Figure 1: Fatigue Cracking

Figure 2: Longitudinal Cracking

Transverse Cracks: These cracks occur perpendicular to the centerline of the pavement, or laydown direction, as shown in Figure 3. Transverse cracks are generally caused by thermally induced shrinkage at low temperatures. When the tensile stress due to shrinkage exceeds the tensile strength of the HMA pavement surface, cracks occur. These cracks can be effectively treated with crack sealants.

Block Cracking: These cracks form regular blocks (Figure 4) and are the result of age hardening of the asphalt coupled with shrinkage during cold weather. They can be effectively treated with crack sealants.



(Direction of Travel →)
Figure 3: Transverse Cracking

Figure 4: Block Cracking

Reflection Cracking: Reflection cracks are caused by cracks, or other discontinuities, in an underlying pavement surface that propagate up through an overlay due to movement at the crack. They exhibit any of the crack patterns mentioned and must be treated according to the original distress mechanism. Figure 5 illustrates reflection cracking in asphalt concrete over portland cement concrete

Edge Cracking: These are crescent-shaped or fairly continuous cracks intersecting the pavement edge and are located within 0.6 m (2 ft) of the pavement edge, adjacent to an unpaved shoulder. They include longitudinal cracks outside of the wheel path and within 0.6 m (2 ft) of the pavement edge (2). Figure 6 illustrates edge cracking. Edge cracks are caused by overloading at the edge of the pavement, shear failure or erosion in the shoulder. This type of cracking cannot always be effectively treated with crack sealants.

Slippage Cracks: These cracks produce a characteristic crescent shape, as shown in Figure 7, and are caused when the top layer of the asphalt shears, often due to high deflections and a poor bond between the layers. This type of cracking cannot be effectively treated with crack sealants.

Figure 5: Reflection Cracking

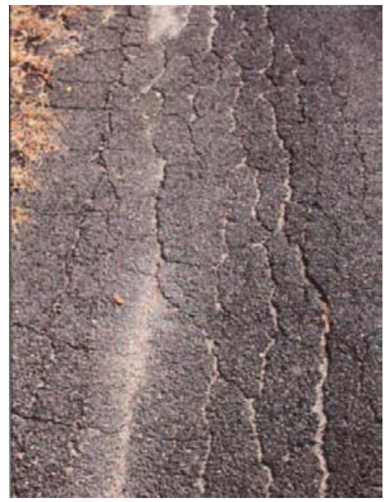


Figure 6: Edge Cracking

Figure 7: Slippage Cracking

1.1.2 Rigid (PCC) Pavements

Joints: Joints in rigid pavements are designed and constructed to permit expansion and contraction of rigid pavements so as to prevent cracking of the slabs between the joints. Typically they are constructed by sawing the concrete shortly after placement of the concrete. Joints may be transverse or longitudinal and are normally sealed during construction and resealed as needed throughout the life of the pavement. Joints are generally straight with vertical cut faces.

Cracks: Cracks in rigid pavements are generally load associated, or due to excessive thermal movement that is not adequately controlled by the joint system. Cracks may be transverse, longitudinal, or angled, especially at slab corners.

1.2 PROJECT SELECTION

Crack sealing and or crack filling may be an option for either surface preparation or surface sealing of a cracked PCC or HMA pavement. Projects are selected on the following criteria:

- The base should be sound.
- Cracks are only sealed or filled when greater than 3mm (0.1 inches) or up to 25mm (1 inch).

1.3 PROJECT PLANNING

Ideally, crack-sealing treatments should be applied when the crack width is at its midpoint to widest, usually in the spring, fall, or winter (i.e., during moderately cold weather conditions). Weather conditions during the time planned for installation need to be appropriate, not too cold or wet. Since non-working cracks do not change in width significantly with temperature, application of crack filling treatments can proceed at any time of the year when weather conditions are appropriate. Traffic passing over a hot applied sealed or filled crack is usually not an issue; however, traffic control during the application of the treatment should be in force long enough to allow for adequate curing of the product and prevent tracking. Sand is typically needed for cold applied systems to prevent tracking. Planning considerations will vary according to the treatment method chosen, for example cold pour materials require different handling than hot pour. Provision must be made to preheat the hot pour before work may commence but cold pour may be used immediately.

1.4 WHETHER TO SEAL OR FILL

The first question to be answered is whether to seal or fill a crack. Cracks may open and close horizontally with temperature and moisture changes and may undergo vertical movements as the result of load applications. Figures 8 and 9 illustrate these mechanisms of crack movement.

In order to determine whether to seal or fill a crack, it must be established whether the crack is working or non-working and whether the crack undergoes horizontal or vertical movement. The total horizontal movement of a crack over the period of one year is the primary determining factor of whether a crack is a working or non-working crack. The Caltrans criteria for a working crack is ≥ 6 mm (1/4 in) of horizontal movement annually (1); FHWA requires only 3 mm (1/8 in) (4). Vertical movement is not usually considered (4). Additionally, the width of the crack plays a role in deciding whether it is a working or non-working crack. Crack sealing is usually triggered when the crack width exceeds 6 mm (1/4 in). Also, the type of the crack can provide an indication of whether it is a working crack or not. Working cracks can be transverse or longitudinal to the pavement, but are most often transverse. Working cracks with limited edge deterioration should be sealed, rather than filled.

When the criteria for working cracks is not met, or when cracks are closely spaced and have little movement, crack filling is less expensive (4). The criteria for deciding whether to seal or fill a crack are listed in Table 1.

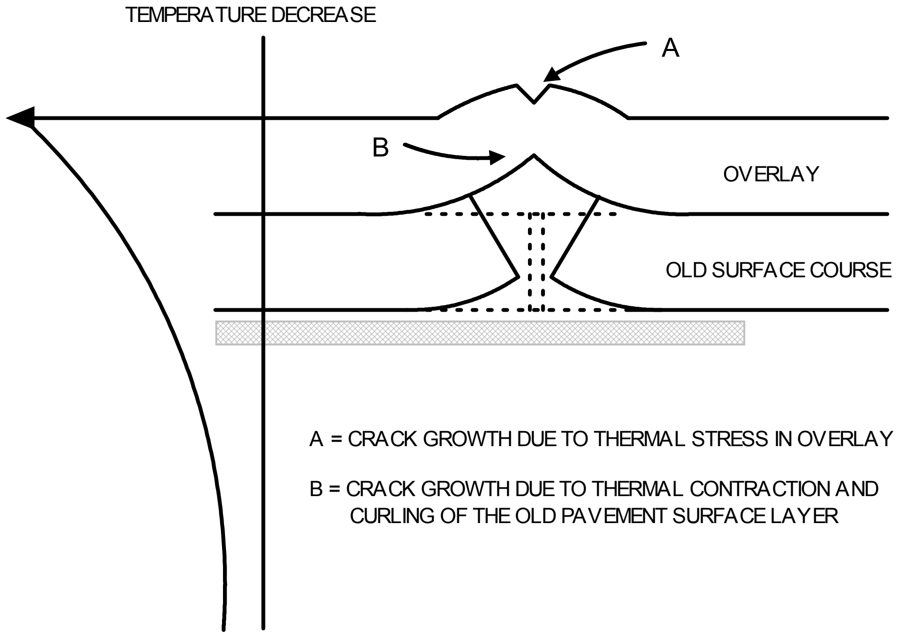


Figure 8: Thermal Effects on Crack Growth (3)

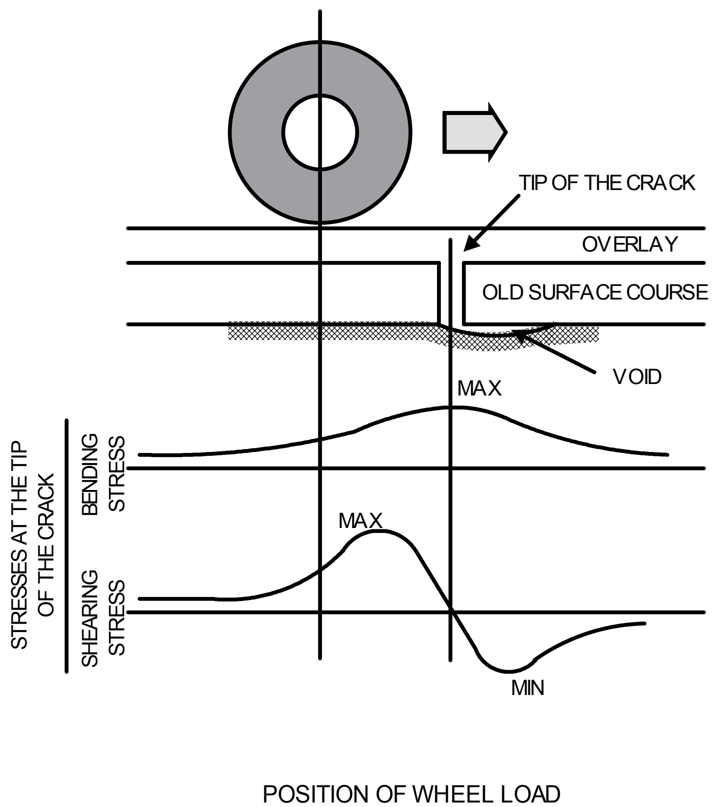


Figure 9: Traffic Load Effects on Crack Growth (3)

Table 1: FHWA Criteria for Crack Sealing or Filling (4)

CRACK CHARACTERISTICS	CRACK TREATMENT ACTIVITY	
	CRACK SEALING	CRACK FILLING
Width	3-25 (mm)	3-25 (mm)
Edge Deterioration	Minimal to None (<25% of crack length)	Moderate to None (<50% of crack length)
Annual Horizontal Movement	≥ 3mm	< 3mm
Type of Crack	Transverse Thermal Cracks Transverse Reflective Cracks Longitudinal Reflective Cracks Longitudinal Cold Joint Cracks	Longitudinal Reflective Cracks Longitudinal Cold Joint Cracks Longitudinal Edge Cracks Distantly Spaced Block Cracks

1.4.1 Crack Sealing

Crack sealing and filling prevent the intrusion of water and incompressible materials into cracks. The methods vary in the amount of crack preparation required and the types of sealant materials that are used.

Crack sealing is the placement of materials into working cracks. Crack sealing requires thorough crack preparation and often requires the use of specialized high quality materials placed either into or above working cracks to prevent the intrusion of water and incompressible materials. Crack sealing is generally considered to be a longer-term treatment than crack filling.

Due to the moving nature of working cracks a suitable crack sealant must be capable of:

- Remaining adhered to the walls of the crack,
- Elongating to the maximum opening of the crack and recovering to the original dimensions without rupture,
- Expanding and contracting over a range of service temperatures without rupture or delamination from the crack walls, and
- Resisting abrasion and damage caused by traffic.

Section 2.1 discusses material requirements in further detail.

1.4.2 Crack Filling

Crack filling is the placement of materials into nonworking or low movement cracks to reduce infiltration of water and incompressible materials into the crack. Filling typically involves less crack preparation than sealing and performance requirements may be lower for the filler materials. Filling is often considered a short-term treatment to help hold the pavement together between major maintenance operations or until a scheduled rehabilitation activity.

Crack filling is for active or non-active cracks created by ageing of the binder. Such cracks are not completely inactive and require some flexible characteristics. A suitable filler material must be capable of:

- Remaining attached to the walls of the crack,
- Possessing some elasticity, and
- Resisting abrasion and damage caused by traffic.

Section 2.1 discusses material requirements in further detail.

1.5 TREATMENT PERFORMANCE

The performance life of a treatment is affected based on the amount of crack preparation and the type of material used (4). It has been found that depending on the amount of preparation and material selection, crack sealants can provide up to 9 years of service and fillers up to 8 years of service (4). In California, overbanded treatments have contributed to poor ride, ride noise and poor surface appearance and are not recommended for use unless it has been squeegeed flush to the surface of the road. It should not be placed more than 12.5mm (1/2 inch) wider than the width of the crack (on both sides of the crack).

Emulsions or asphalt materials placed in a flush configuration in unrouted cracks (see Section 2.4) can provide 2 to 4 years of service while hot applied rubber and fiber modified asphalt fillers placed in flush or overbanded configurations (Section 2.4) can provide 6 to 8 years of service (4).

Several methods exist for evaluating a treatment's performance. One method is based on determining a treatment's effectiveness. Treatment effectiveness is the success of the treatment measured as a percentage of the total treatment that has not failed (4). In order to determine the condition of a treatment, visual inspections of the treated areas are required. Inspections for treatment failure should be carried out once per year (4).

1.5.1 Treatment Failures

Treatment failures can be attributed to improper treatment selection, improper material selection, poor workmanship, and improper application or lack of post-treatments. Common treatment failures include:

- **Adhesion loss:** The sealant does not adhere to the sides or bottom of the crack.
- **Cohesion loss:** The sealant fails in tension by tearing.
- **Potholes:** The crack is not completely sealed, allowing water into the pavement. Continued deterioration leads to pumping and pothole formation.
- **Spalls:** The edges of the crack break away as a result of poor routing or sawing.
- **Pull-on:** The sealant is pulled out of the crack by tire action.

1.5.2 Treatment Effectiveness

The firs step in determining a treatment's effectiveness is establishing how much of the treatment has failed in relation to the total length of treatment applied (% failure). Once the amount of treatment failure is determined, the treatment's effectiveness can be calculated using the following expression (4).

Effectiveness = 100 - % failure…………….………………………………(2.1)
Where: % Failure = 100 X [Length of Failed Treatment / Total Length of Treatment]

By routinely monitoring treated areas, a graphical representation of a treatments' effectiveness can be generated like the one shown in Figure 10. From this figure, the projected life of the treatment used on this cracked area can be projected as the time at which the effectiveness has dropped to 50% (as defined above). Graphs like these can be used to determine when additional treatments may become necessary (4).

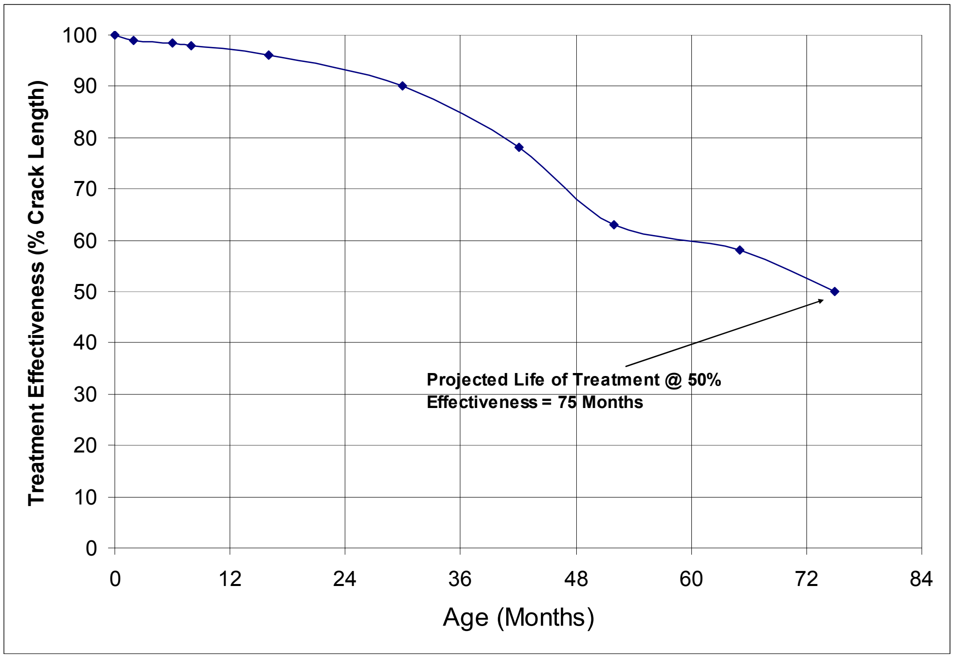


Figure 10: Treatment Effectiveness (4)

1.5.3 Cost Effectiveness

The cost effectiveness of a treatment can be determined readily once the treatment effectiveness has been determined. Cost effectiveness is the total cost of a treatment divided by its effectiveness. Cost effectiveness may be converted into an annual cost by dividing the cost effectiveness by the number of years required to reach 50% effectiveness.

2.0 MATERIALS

Crack sealing and filling material specifications for Caltrans fall under SSP 37-400 (7), 41-200 (8), 51-740 (9) and Standard Specifications Section 94 (10). The materials and methods discussed below apply to HMA pavements unless specified otherwise.

2.1 MATERIALS

2.1.1 Materials for Crack Sealing

Crack sealing materials are designed to adhere to the walls of the crack, stretch with the movement of the crack over the range of conditions and loads associated with the crack location, and resist abrasion and damage caused by traffic. For sealing working cracks, the preferred sealant is usually elastomeric. This means the sealant has a low modulus of elasticity and will stretch easily and to high elongations (usually around 10 times its non strained dimensions) without fracture. Such sealants also recover over time to close to their original dimensions. The sealants are usually applied at elevated temperatures due to their high viscosity at ambient temperatures and they set or cure by cooling and reforming into complex structures. This is called thermoplastic. Thermoset is sometimes used to describe these materials, however this is incorrect. A thermoset is a material that undergoes a chemical cross-linking when heated. This structure is retained as it cools and is not reversible by reheating. Thermoplastics form physical structures on cooling but this process is reversible with reheating. Hot application ensures good adhesive bond to the crack walls. In California most of the hot pour materials are rubber-modified asphalt. These materials have excellent abrasion resistance and are useful for trafficked surfaces.

Cold pour materials for crack sealing in California are usually silicone based and often used prior to paving. These materials cure either by exposure to moisture in the air or by mixing a hardening agent with the base silicone. These materials often have poor abrasion resistance and should not be used in trafficked areas. Other materials such as epoxies and polyurethanes are almost always cured by addition of a second chemical.

2.1.2 Materials for Crack Filling

For crack filling applications, the cracks are basically inactive (non-working). Crack filling materials are designed to adhere to the walls of the crack, and resist abrasion and damage caused by traffic.

Crack filling materials may be hot applied rubber or polymer asphalts, or cold applied emulsion-based products. The emulsion products assist with forming a good adhesive bond with the crack wall and additives such as Styrene Butadiene Rubber (SBR) latex ensure that the material can endure some degree of movement. In some cases, hot applied fiber modified asphalt binders may be used.

Table 2 lists Caltrans and AASHTO specifications for various crack sealants and fillers. In addition, it provides approximate costs and service lives of these materials.

Table 2: Crack Sealer and Filler Specifications

Material	Specifications (CT/ AASHTO)	Application Type	Approx. Costs ($/kg)	Approx. Life (Years)
Asphalt Emulsion	CT section 94/ M140, M208	Filling	0.15-0.30	2-4
Asphalt Cements	CT section 94/ M20, M226	Filling	0.03-0.15	2-4
Fiber Modified Asphalt	No Specification	Filling	0.35-0.60	6-8
Polymer Modified Emulsion (PME)	CT section 94/ M140, M208	Filling (minor sealing)	0.80-1.20	3-5
Asphalt Rubber (AR)	CT SSP 37-400	Sealing	0.45-0.60	6-8
Specialty AR Low Modulus	CT SSP 37-400	Sealing	0.75-1.40	5-9
Silicone	CT SSP 41-200, SSP 51-740	Sealing	5.75-6.75	4-6

2.2 STORAGE AND HANDLING OF MATERIALS

Chapter 1 of this manual identifies procedures for material storage and handling. In all cases, the manufacturer's recommendations for storage and handling should be closely followed.

Hot pour materials require very high temperatures, typically between 188 to 200°C (370 to 390°F) (4). These materials may degrade or cross link when exposed to excessive temperatures for long periods of time. For this reason, the manufacturer's recommendations must be followed exactly.

2.3 MATERIAL PLACEMENT METHODS

Once a suitable seal or fill material has been selected, as set forth in Caltrans Standard Special Provisions SSP 37-400 (7), the appropriate placement method must be determined. Placement methods vary according to the nature of the distress. When selecting the placement method, one should consider the method's applicability to: 1) the type of distress, 2) the dimensions of the crack channel, 3) the type of crack channel (cut or uncut), and 4) the finish requirements. Each method carries its own set of job equipment and preparation requirements. Placement methods include:

- Flush Fill
- Overband
- Reservoir
- Combination: Reservoir w/Band-Aid
- Combination: Sand Fill w/ Recessed Finish
- Backer Rod

2.3.1 Flush Fill Method

In the flush fill method, fill material is forced into an existing uncut crack. Once filled, the crack is struck off flush with the pavement. Figure 11 illustrates the flush fill method.

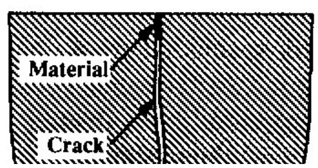
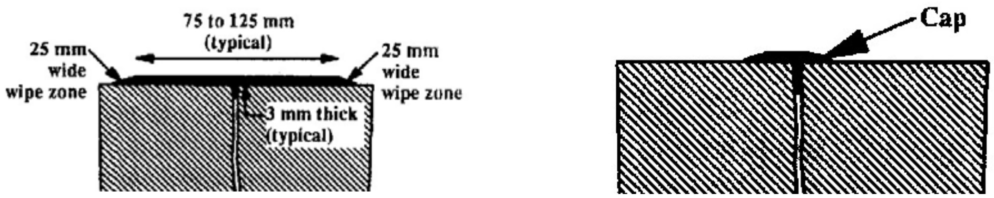


Figure 11: Flush Fill Method (4)

2.3.2 Overband Method

In the overband method, fill material is forced into and placed over an uncut crack. If the fill material is squeegeed flat, it is referred to as a 'Band-Aid'; if not; it is referred to as capped. Overbanding and capping should not be done if silicone has been chosen as the fill material. This is due to silicone's poor abrasion resistance. Figure 12 illustrates the overband method with both finishing options.



a) Simple Band-Aid **b) Capped**

Figure 12: Overband Method (4)

Caltrans does not recommend this practice and advises that all crack sealing and filling be squeegeed if material is left above the surface. Overbanding can create a rough ride and/or excess road noise and causes problems when placing subsequent overlays.

2.3.3 Reservoir Method

In the reservoir method, the crack is cut or routed to form a reservoir that is filled with a sealant. The sealant may be left flush or slightly below the surface of the reservoir. The depth and width of the reservoir varies according to job requirements. Saw depths will be greatest when working with very active cracks and cracks in PCC pavements. Crack cutting will often depend on the number of cracks and whether the cutter can follow the shape of the crack. Typical reservoir widths range from 12 to 25 mm (0.5 to 1.0 in), and even up to 38 mm (1.5 in) in very cold climates. Reservoir depth ranges from 12 to 25 mm (0.5 to 1.0 in). Reservoir use is appropriate for pavements in good condition, without extensive cracking amounts. Crack cutting units, when operated by trained, experienced personnel, can follow meandering random cracks. Figure 13 illustrates the reservoir method.

2.3.4 Combination Method: Reservoir with Band-Aid

This combination method involves the formation of a 'Band-Aid' over the top of a cut reservoir. Figure 14 illustrates the combination method. Like the overband method, the combination method should not be used with materials that are prone to pickup due to traffic or materials with poor wearing characteristics (4). The combination method can be used on heavily trafficked roads, but care must be taken to squeegee excess material off the surface.

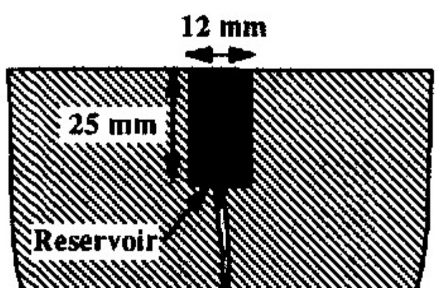


Figure 13: Reservoir Fill Method with Flush Finish (4)

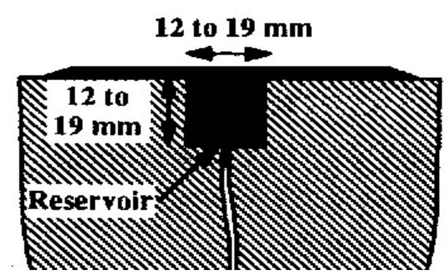


Figure 14: Combination Fill Method (4)

2.3.5 Combination Method: Sand Fill with Recessed Finish

Thermal cracking can develop over time and penetrate the full depth of asphalt pavement in a roadway. As thermal cracks progress down through the asphalt layers, they typically continue to widen and it is not unusual for such cracks to be 12 to 25 mm (0.5 to 1 in) or wider and exceed 102 mm (4 in) in depth. If these types of cracks are sealed or filled full depth, the large volumes of filler or sealer tend to soften and migrate under loads in hot weather, and begin to pull out under traffic. If an overlay is applied, the heat of the new mat will draw the filler and sealer materials up through the overlay. In areas with heavy sealer or filler applications, fat spots, flushing, and shoving in the overlay can occur. These symptoms can only be remedied by changes in construction procedures or the removal and replacement of the affected materials.

Sealant application should not exceed 25 mm (1 in) in depth. For full depth wide cracks, backer rod can be used to limit sealant depth. Another method that can be used is to partially fill the crack with sand. Blow out any debris with air, fill the crack with clean sand to a point approximately 19 to 25 mm (0.75 to 1 in) below the adjacent pavement surface, and tamp lightly as needed with a steel rod or piece of rebar to reduce any large voids in the sand. Then apply the crack sealer over the top of the sand and along the crack faces, the surface of the sealant should be cupped slightly below the adjacent pavement surface. This recessed finish allows some movement of the crack and sealer material without creating an undesirable hump on the surface. This fills and seals the deep wide crack while limiting the impact on subsequent paving operations. Figure 15 illustrates this combination method.

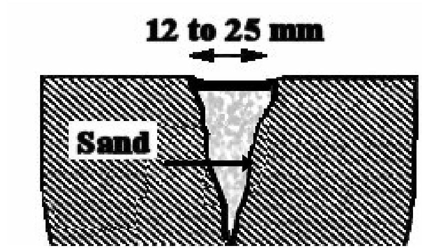
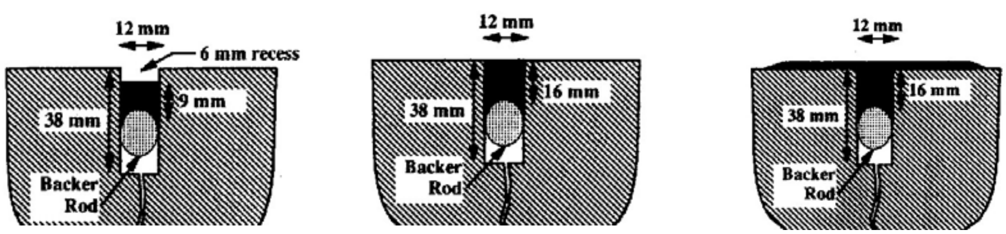


Figure 15: Combination: Sand Fill with Recessed Finish

2.3.6 Backer Rod (PCC Pavements)

Joint sealing applications for PCC pavements may require the incorporation of a backer rod or bond breaker. The backer rod, typically polyethylene foam, is placed within a crack or joint to prevent the sealant from sticking to the reservoir bottom and to restrict the sealant depth to the upper portion of the joint. A backer rod is also incorporated in very large cracks or joints and when silicone is being used. Currently, Caltrans does not use self-leveling silicones. A backer rod is only used if it is cost effective and the cracks are relatively straight like those occurring in PCC joints. Figure 16 shows three typical backer rod configurations.



a) Recessed Finish **b) Flushed Finish** **c) Capped Finish**

Figure 16: Three Common Backer Rod Configurations (4)

2.4 SELECTING THE APPROPRIATE PLACEMENT METHOD

The appropriate placement method should be based on the governing considerations of the project. Governing project considerations include:

- Type and extent of the sealing or filling operation,
- Traffic conditions,
- Crack characteristics,
- Material requirements,
- Desired performance (expectations),
- Aesthetics, and
- Cost.

Table 3 outlines method placement issues in relation to governing project considerations.

Table 3: Placement Method Considerations (4)

Project Consideration	Method Applicability
Type and Extent of Operation	Most filling operations, and some sealing operations, omit crack cutting operation. However, many northern States have found crack cutting necessary and desirable for cracks exhibiting significant movements.
Traffic	Overband configurations experience wear and, subsequently, high tensile stresses directly above the crack edges, leading to adhesive edge separations. Thus, overband configurations should be avoided for sealing cracks on heavily trafficked roads.
Crack Characteristics	Overband configurations are appropriate for cracks having a considerable amount of edge deterioration (> 10 percent of crack length); because the overband simultaneously fills and covers the deteriorated segments in the same pass. Reservoir methods without overbanding should not be used on cracks with edge deterioration.
Material Type	Materials such as emulsion, asphalt cement, and silicone must be placed unexposed to traffic due to serious tracking or abrasion problems.
Desired Performance	For long-term sealant performance flush reservoir, and recessed band-aid configurations provide the longest life.*
Aesthetics	Overband and combination configurations detract from the general appearance of the pavement.
Cost	Omission of crack cutting operation reduces equipment and labor costs but may decrease treatment longevity. Combination configurations require significantly more material than reservoir configurations, resulting in higher costs. The placement method impacts the type of material to use as well so costs may be higher for specialty materials (see Table 2).

** Ride Quality is an important consideration*

3.0 CONSTRUCTION

3.1 SAFETY AND CONTROL

The Resident Engineer (RE) can examine and approve the contractor's traffic control plan prepared in accordance with the Caltrans Safety Manual (11) and the Caltrans Code of Safe Operating Practices (12). The signs and devices used must match the traffic control plan. The work zone must conform to Caltrans practice and requirements set forth in the Caltrans Safety Manual and the Caltrans Code of Safe Operating Practices. All workers must have all required safety equipment and clothing. Signage shall be removed when it no longer applies.

3.2 EQUIPMENT REQUIREMENTS

Equipment requirements vary according to the treatment method chosen. Equipment may be required for:

- Routing or Sawing,
- Crack Cleaning and Drying,
- Backer Rod Placement (PCC Pavements),
- Application of Sealer or Filler,
- Finishing Method, and
- Trafficking and Subsequent Treatments.

Equipment requirements are covered in more detail in Sections 3.4 through 3.7 of this chapter.

3.3 CLIMATIC CONDITIONS

Crack sealing treatments should be placed when the cracks are at their midpoint to maximum point of expansion. This is not always practical since cracks are at their maximum point of expansion during the coldest months. Most crack fillers and sealants have limitations to their ability to wet and form films at low temperatures. This is due to either a high viscosity or the fact that they are emulsified. Additionally, winter climates make working conditions difficult and in some regions impossible. Bearing these considerations in mind, the fall is typically the best time for application. At this time air temperature are typically between 7°C and 18°C (45 to 65°F) in most parts of California. Under these conditions, cracks are usually at or near their mid-point of movement, which helps to ensure that the crack sealant or filler will not be extended or compressed too much when temperatures increase or decrease, respectively, following application of the sealant or filler. In addition, application during the fall (i.e., at moderate temperatures) ensures that temperatures have not dropped to a point where sealants will have difficulty wetting the crack walls or forming continuous films. In colder climate areas, spring and fall work conditions are required to allow workers to properly prepare the pavement surface and install products.

3.4 PREPARATION

Site preparation requirements vary according to the sealing or filling method and materials chosen for the project. The following paragraphs describe site preparation in further detail.

3.4.1 Routing or Sawing

When routing or sawing is incorporated, cracks need to be cleaned and dried prior to application of the filler or sealant. When pavements are cracked extensively, routing or sawing of cracks may not be appropriate. Crack cutting becomes especially important in climates where crack movement is very high. Crack cutting allows more filler to be used and provides better control of the crack channel shape. Secondary cracks along the primary crack are not usually routed. Routing is generally not used in HMA or PCC pavements in California. Crack cutting and routing equipment includes vertical spindle routers, rotary impact routers, and random crack saws. Damage to the pavement should be kept to a minimum by clean cutting. The use of carbide bits improves the quality of cutting and typically produces clean reservoir cuts. Figure 17 illustrates a rotary impact router in use.

Figure 17: Crack Routing Operation

3.4.2 Cleaning and Drying

Debris left in a crack, resulting from sawing, routing, or pavement use will affect the adhesion of the sealant or filler. Debris also contaminates the sealing or filling material and reduces cohesion. Reduced adhesion or cohesion normally results in early failures. To avoid these contamination-related failures, sawed or routed cracks must be cleaned prior to being treated. Several cleaning methods can be used, including:

- Air blasting,
- Hot air blasting,
- Sand blasting, and
- Wire brushing.

Air blasting involves directing a concentrated stream of air into the crack or joint to blow it clean. Air blasting equipment is effective and efficient for cleaning cracks. Air blasting is not efficient for drying cracks. Should a crack require drying, hot air blasting should be used. Air pressure should be a minimum of 670 kPa (97 psi) with a flow of 0.07 m^3/s (2.5 ft^3/s). Air blasting equipment must be equipped with moisture and oil traps.

Hot air blasting is done using a hot compressed air heat lance. While cleaning and drying the crack, hot air blasting also promotes enhanced bonding associated with the crack edges being warmed. Care must be taken to ensure that the pavement is not overheated or heated for excessive periods of time as this will result in unnecessary hardening of the asphalt binder in the pavement adjacent to the crack.

Sand blasting involves directing a stream of sand entrained in compressed air into the crack. The abrasive nature of the sand cleans the crack or joint. Sandblasting, which is used for cleaning cracks in PCC pavements by many states, is an effective treatment. However, sandblasting is messy and typically requires a two-phase operation. The first operation is cleaning the joint surface; the second cleans the sand from the joint and its surroundings. On new PCC pavements, sand blasting is required to clean the surface prior to applying the sealant.

Wire brushing or brooming involves the use of a wire broom stock or stiff standard broom to brush out the crack or joint. Wire brushing can be an effective cleaning method. Wire brushing may be done manually or using power driven brushes. Figure 18 illustrates the manual crack cleaning method using a broom

3.4.3 Backer Rod (PCC Pavements)

Installation of a backer rod should be performed once a joint or crack channel has been cleaned. Installation of the backer rod into the channel is accomplished either by manual means or through the use of a specialized three-wheel tool. Two wheels ride on either side of the crack while the third rolls the backer rod into the crack channel. Figure 19 illustrates a backer rod installed in a crack channel.

3.4.4 Application of Sealer or Filler

The material selected will in part, determine the application method. Typically, asphalt emulsions are applied directly to the cracks. Hot applied rubber modified sealants, especially asphalt rubber, have excellent adhesion and do not require the application of a thin sand coating (blotter coat) prior to trafficking. Emulsions must be blotter coated prior to being trafficked. Emulsions may be applied via gravity feed devices, such as pour pots, or via pressure hoses. Some emulsions may require heating to achieve appropriate application viscosity. Hot applied rubberized sealants need to be agitated and heated and maintained at the correct temperature throughout their application. For polymer and rubber modified materials, control of temperature is important in preventing degradation. For hot applied fiber filled materials, the fiber may settle; therefore, agitation is required. For such materials indirect oil heating is recommended. Required capacity of sealant or filler application equipment is determined by the job size. Preheating the material before use is advisable to ensure productivity is optimized. Figure 20 illustrates a hot pressure feed sealing operation and a gravity fed pour pot.

The application rate of a sealant or filler plays an important role in the quality of a crack sealing or filling project. Problems associated with over applied sealer or filler material include fat spots, localized tenderness, and flushing when treated areas are overlaid with hot mix.

Figure 18: Manual Crack Cleaning

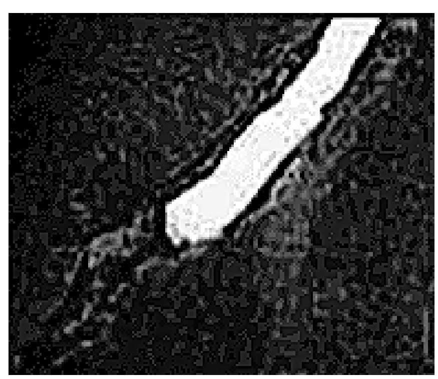


Figure 19: Backer Rod Installed Into Crack Channel

a) Hot Pressure Fed **b) Pour Pot**

Figure 20: Application Techniques and Equipment

3.5 FINISHING

Finishing techniques will vary depending on the application and type of material chosen. Flush finishes and overbanding methods require the use of a squeegee. In some cases, a preformed plate on a hand lance assists in making the required flush result. Figure 21 shows three typical flat finishing techniques. As stated earlier, all sealant left on the surface shall be squeegeed to prevent a rough ride and is the only method recommended by Caltrans.

a) Squeegee **b) Flat Plate Use** **c) Over Banding**

Figure 21: Typical Flat Finishing Techniques

Blotter coats of clean sand are usually used with emulsion crack filling to prevent pick-up of an overband. A blotter coat is often used to prevent pick-up upon re-opening to traffic. To ensure a high quality blotter coat, only clean and dry sand should be used. Figure 22 illustrates the brooming of a blotter coat over a treated crack. This practice is not recommended by Caltrans as it leaves broom marks and voids in the sealant.

Figure 22: Brooming Blotter Coat Over a Treated Crack

3.6 TRAFFICKING AND SUBSEQUENT TREATMENTS

Sealants and fillers undergo a curing cycle depending on the type of material used. Emulsions cure by water loss and reduce in volume. This process usually takes several days and creates a concave surface in the crack. Generally, cracks filled with these materials should not be overlaid for at least a year. Trafficking should not be allowed until after the emulsion has set sufficiently so that tires passing over the sealant/filler won't pick it up. Caltrans normally sands the sealer prior to opening to traffic.

Hot applied materials are thermoplastic; they set when they cool provided no diluents, such as solvents, are used in their formulation. These materials produce a non-tacky finish once the material reaches ambient temperature. A blotter coat can assist in this process. In addition, hot applied sealants require a three to four month cure time prior to being covered with a blanket or seal. Hot applied materials should not be placed over cold mix patches. This hot applied material will pick up, pulling the patch out.

Silicone, along with two-part systems (used in PCC pavements), cure by cross-linking either due to ambient moisture or a two-part chemical reaction. When using these materials the manufacturers' recommendations must be followed. Overbanding and capping must not performed when using these materials and they should be applied such that they do not receive direct traffic. Sanding the fresh crack seal reduces safety concerns (slick pavements) and improves the surface appearance (aesthetics). Excess sand must be swept away before opening the road to traffic. Cold applied sealants require a one year cure time prior to being covered with a blanket or seal.

3.7 JOB REVIEW - QUALITY ISSUES

Quality issues are typically related to the poor choice of sealing and filling methods and poor workmanship. Common examples of poor sealing and filling methods include excessive use of sealant and multiple uses of treatments over several years. One common example of poor workmanship includes over-filling without proper finishing. Figures 23 through 25 illustrate these commonly addressed quality issues. These practices directly impact traffic safety, smoothness and appearance for users.

Figure 23: Excessive Sealant

Figure 24: Multiple Treatments

Figure 25: Poor Workmanship – Raised, Bumpy Sealing

4.0 TROUBLESHOOTING

This section provides information to assist the maintenance personnel with troubleshooting problems with crack sealing and crack filling projects. Appendix A discusses some field considerations to assist the development of successful jobs.

4.1 TROUBLE SHOOTING GUIDE

The troubleshooting guide presented in Table 4 associates common problems to their potential causes. For example, a sealant separating from the sides of a crack may be caused by application to a wet crack surface, dirty crack surface, poor material finishing technique, application of cold sealant, insufficient material, rain during the application, or application during cold weather. Appendix A lists field considerations to ensure a successful outcome.

Table 4: Trouble Shooting Crack Sealing and Filling Projects

	PROBLEM						
	ALL SEALS			EMULSION SEALS ONLY			
CAUSE	Tacky Picks Up	Re-Cracks Quickly	Bumpy Surface	Separation From Crack Sides	Emulsion Sealer Not Breaking	Emulsion Sealer Breaks Too Fast	Emulsion Sealer Washes Off
Crack Wet					●		●
Sealant Not Cured	●			●		●	
Crack Dirty	●	●		●		●	
Insufficient Sanding	●			●		●	
Poor Finish, Wrong Tools	●	●	●	●		●	
Sealant Too Cold		●	●				
Sealant Too Hot	●			●			
Application Too High	●		●	●			
Application Too Low		●	●				
Sealant Degraded Due to Overheating	●	●	●	●	●	●	●
Rain During Application					●		●
Cold Weather		●			●		
Hot Weather	●		●	●		●	

In addition to the troubleshooting guide, Table 5 lists some commonly encountered problems and their recommended solutions.

Table 5: Common Problems and Related Solutions

Problem	Solution
TRACKING	▪ Reduce the amount of sealant or filler being applied. ▪ For hot applied materials, allow to cool or use sand or other blotter. ▪ Allow sufficient time for emulsions to cure or use a sufficient amount of sand for a blotter coat. ▪ Ensure the sealer/filler is appropriate for the climate in which it is being placed.
PICK OUT OF SEALER	▪ Ensure cracks are clean and dry. ▪ Increase temperature of application. ▪ Use the correct sealant for the climate. ▪ Allow longer cure time before trafficking.
BUMPS	▪ Check squeegee and ensure it is leaving the correct flush finish. ▪ Have squeegee follow more closely to the application. ▪ Decrease the viscosity of the sealer. ▪ Change the rubber on the squeegee.

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APPENDIX A

SUGGESTED FIELD CONSIDERATIONS

The following field considerations are a guide to the important aspects of performing a crack sealing or crack filling project. The various tables list items that should be considered in order to promote a successful job outcome. As thoroughly as possible, the answers to these questions should be determined before, during, and after construction. The staff to do this work will vary by job type and size. Some topics may need attention from several staff members. The field supervisor should be acquainted with its contents. The intention of the tables is not to form a report, but to bring attention to important aspects and components of the project process. Some information is product specific and contained in the relevant standard specifications, special standard provisions, or special provisions.

PRELIMINARY CONSIDERATIONS	
PROJECT REVIEW	▪ Is the project a good candidate for crack sealing or filling? ▪ What type of cracking exists? How severe is it? How much is there? ▪ Are there base failures along the project? ▪ How much bleeding or flushing exists? ▪ Is the pavement raveling or oxidized? ▪ What is the traffic level? ▪ Is the base sound and well drained? ▪ Would a membrane (SAM, SAMI) treatment be a better solution? ▪ Review project for bid/plan quantities.
DOCUMENT REVIEW	▪ Crack activity (movement) information. ▪ Application specifications. ▪ Construction manual. ▪ Special provisions. ▪ Traffic control plan.
DETERMINING APPLICATION TYPE	▪ What type of application is being used? ▪ Are agency guidelines and requirements being followed? ▪ Are the cracks being sawn or routed? ▪ Is a bond beaker being used?
MATERIAL CHECKS	▪ Has a crack survey been done? ▪ Has the amount of filler/sealer material required been calculated for the number and length of cracks being treated? ▪ Has the sealer or filler been produced by an approved source? (if required) ▪ What is the application temperature and the safe heating temperature? ▪ What special handling requirements are needed: heating rate, allowable storage time at high temperatures, cold application? ▪ Has the sealer or filler to be used been sampled and submitted for testing? ▪ Is a blotter coat required? Is clean, dry sand available?

PRE-SEAL INSPECTION CONSIDERATIONS	
SURFACE PREPARATION	▪ Do the cracks need to be sawn or routed? ▪ Are secondary cracks to be sawn or routed? ▪ Have the cracks been cleaned? ▪ Have oily residues been scrubbed from the pavement? ▪ Has the surface been cleaned, dried, and broomed?
WEATHER REQUIREMENTS	▪ Air and surface temperatures have been checked at the coolest location on the project? ▪ Air and surface temperatures meet agency and sealant/filler manufacturer requirements. ▪ Application should not begin if rain is likely. ▪ Application should not begin if freezing temperatures are expected.
TRAFFIC CONTROL	▪ The signs and devices used match the traffic control plan. ▪ The work zone complies with Caltrans traffic control policies as described in the Caltrans Safety Manual (9). ▪ Flaggers do not hold the traffic for extended periods of time. ▪ Unsafe conditions, if any, are reported to a supervisor. ▪ Signs are removed or covered when they no longer apply.
EQUIPMENT INSPECTION AND CONSIDERATIONS	
SAWING/ ROUTING UNIT	▪ Is a saw or router to be used? ▪ Is the unit fully functional? ▪ Are the cutting bits sharp to avoid spalling or cracking? ▪ Are the cutting bits the correct size? ▪ Is all equipment free of leaks? (Hydraulic oil, diesel, motor oil etc.)
SEALING UNIT	▪ Is the sealing unit functional? ▪ Are the moisture and oil filters on the compressor clean and functioning? ▪ Does the unit have temperature control (for hot applied sealants)? Is the temperature controller working properly and is the measuring device calibrated? ▪ Does the sealing unit provide adequate pressure to deliver material to the crack at an appropriate rate? ▪ Is a pour pot being used? ▪ Is a kettle applicator being used? Is the kettle being kept at least partially full at all times? ▪ Is the applicator unit re-circulating during idle periods? ▪ What method is being used to ensure that the crack sealant or filler is flush with the pavement surface? ▪ Is all equipment free of leaks? (Hydraulic oil, diesel, motor oil etc.)

PROJECT INSPECTION CONSIDERATIONS	
CRACK SEALING OR FILLING APPLICATION	▪ Does the operator have safety gear appropriate for the job? ▪ Have the cracks been mapped? ▪ Does the cutting/routing follow the crack as closely as possible? ▪ Are cut dimensions satisfactory? ▪ Are the cracks dry at the time of sealing? ▪ Is there a backer rod? Is it properly installed; straight, not twisted or damaged? ▪ Is the backer rod placed to the specified depth? ▪ Is the backer rod compressed correctly in the crack channel? ▪ The sealing operation must follow directly behind the cutting/cleaning/drying operations? ▪ Sealant flows evenly with no surging? Vat to be kept at least part full at all times. ▪ Is the sealant at the correct application temperature? ▪ Check sealant temperature at nozzle using high temperature thermometer or infrared thermometer. ▪ Is the squeegee shape correct and not worn, clean and free of carbon or filler build up, operated at the correct distance from the crack, and centered on the crack? ▪ Sealant is even and consistent and has not been reheated more than the allowable number of times and for the recommended periods of time? ▪ Are there excessive bubbles in the material caused by water? ▪ Confirm that crack channel is filled from the bottom up and not overfilled. ▪ Does the application have an even and uniform finish, flush with the pavement surface? ▪ Reapply sealant to any areas that are under filled. ▪ The application is stopped as soon as any problems are detected. ▪ Check bond by peeling the filler or sealant. ▪ Do not traffic until the sealant or filler does not track under traffic.
CLEAN UP	▪ All material spills are cleaned up. ▪ All loose sand is removed from the traveled way.